

On the Threshold of New Physics?

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Abstract

In May 2008 the long awaited NASA Satellite, GLAST was launched, which will study cosmic gamma rays. In August 2008, it is expected that the CERN's Large Hadron Collider (LHC) will finally become operationized. This is found to unwind several new particles. All this has the potential of opening the frontier of a New Physics.

1 Introduction

Particle Physics has stagnated for over three decades. Undoubtedly the standard model has been a great success, but only at relatively low energies less than about 200GeV and it is certainly not the whole story given the fact that there are eighteen arbitrary parameters and so on. Moreover the discovery of the neutrino mass in the late nineties in the Super Kamiokande experiment (a prediction made earlier by the author [1] and references therein) is a definite indication that we need to look beyond the standard model in which the neutrino has vanishing mass. A very important shortcoming has been the fact that the Higgs Boson has been elusive for over four decades.

At another level, there have been a few contra events observed in high energy cosmic rays that hint at corrections to Lorentz symmetry itself (Cf.[2] and other references therein).

In May this year, NASA's GLAST Telescope finally lifted off and it is expected that in the next few years it will study gamma rays and will shed light on some of these puzzles. So also, the physics community is looking forward to the operationalization of Large Hadron Collider (*LHC*) in August. This

will be the most powerful Particle Accelerator for many years to come. This will undoubtedly provide a wealth of information over the years. Let us now look at these two important events and possibilities.

2 Gamma Rays

Recently the MAGIC Gamma Ray Telescope in Spain detected a big Gamma Ray flare in the galaxy Mkn 501. It was observed that the luminosity of the galaxy doubled in two minutes and that there was a four minute lag between the arrival times of gamma photons with energy greater than 10 TeV as compared to 100 GeV photons. This was sought to be explained by Ellis et al as a Quantum Gravity effect in which there is a dispersion in the velocities of the photons with respect to frequency [3]. The authors used the timing of the photons observed by the MAGIC Gamma Ray Telescope during a flare of the above galaxy and investigated a vacuum refractive index

$$1 - (E_0/E')^n, \quad n = 1, 2$$

which might represent the effect inducted by Quantum Gravity. They found that the peaking of the flare maximized for a Quantum Gravity mass scale $\sim 0.4 \times 10^{18} GeV$ or $0.6 \times 10^{11} GeV$ for $n = 1, 2$. They could get lower limits of respectively $0.26 \times 10^{18} GeV$ or $0.30 \times 10^{11} GeV$ at the ninety five percent confidence level. The sensitivity of the MAGIC telescope at these levels of confidence was confirmed by Monte Carlo studies. This does not rule out the contribution of other possible source effects. They obtained, finally,

$$c' = c(1 - \frac{E_0}{E'})$$

where c' is the modified velocity of the photons and E' is their estimate for the Planck energy, which turned out to be about one percent of the actual value. Our work on a non commutative spacetime predicts a similar effect. This is due to the modified energy momentum dispersion relation deduced from theory [4, 5, 6].

Based on our earlier considerations, we can deduce from theory that the usual energy momentum formula is replaced by ($c = 1 = \hbar$) (Cf.[5, 7])

$$E^2 = m^2 + p^2 + \alpha l^2 p^4 \tag{1}$$

where α is a dimensionless constant of order unity. (For fermions, α is positive). To see this in greater detail, we note that, given a minimum fundamental length l , the usual Quantum Mechanical commutation relations get modified and now become, as shown a long time ago by Snyder,

$$[x, p] = \hbar' = \hbar \left[1 + \left(\frac{l}{\hbar} \right)^2 p^2 \right] \text{ etc,} \quad (2)$$

$$[x, y] = O(l^2) \text{ etc.}$$

where we have temporarily re-introduced \hbar (Cf. also ref.[8]). (2) shows that effectively \hbar is replaced by \hbar' . Interestingly (2) is Lorentz invariant for any minimum length l . In our usual (commutative) spacetime, the left side of (2) would vanish for coordinates x and y . Strictly speaking relations (2) would hold in Quantum Gravity approaches and even M theory. So, from (2), we get, with the new \hbar' ,

$$E = [m^2 + p^2(1 + l^2 p^2)^{-2}]^{\frac{1}{2}}$$

So the energy-momentum relation leading to the Klein-Gordon Hamiltonian is now given by, from the above,

$$E^2 = m^2 + p^2 - 2l^2 p^4, \quad (3)$$

neglecting higher order powers of l .

For Fermions the analysis can be more detailed, in terms of Wilson lattices [9]. The free Hamiltonian now describes a collection of harmonic fermionic oscillators in momentum space. Assuming periodic boundary conditions in all three directions of a cube of dimension L^3 , the allowed momentum components are

$$\mathbf{q} \equiv \left\{ q_k = \frac{2\pi}{L} v_k; k = 1, 2, 3 \right\}, \quad 0 \leq v_k \leq L - 1 \quad (4)$$

(4) finally leads to

$$E_{\mathbf{q}} = \pm \left(m^2 + \sum_{k=1}^3 a^{-2} \sin^2 q_k \right)^{1/2} \quad (5)$$

where $a = l$ is the length of the lattice, this being the desired result. (5) shows that α in (1) is positive. We have used the above analysis to indicate

that in the Fermionic case, the sign of α is positive.

A rigid lattice structure imposes restrictions on the spacetime - for example homogeneity and isotropy. Such restrictions are not demanded by fuzzy spacetime, and we use the lattice model more as a computational device (Cf. ref.[5] and [2]). This leads to a modification of the Dirac and Klein-Gordon equations at ultra high energies (Cf.ref.[5, 7, 10]). It may be remarked that proposals like equation (1) have been considered by several authors though from a phenomenological point of view (Cf. refs.[11]-[20]). Our approach however, has been fundamental rather than phenomenological in that we start with (2) and deduce (3).

Using (3), we can easily deduce that

$$E^2 = E_0^2(1 - \frac{E_0^2}{E''^2})$$

This gives

$$c'^2 = c^2(1 - \frac{E_0^2}{E''^2}) \quad (6)$$

where E'' is the actual Planck energy. On the other hand from the equation above of Ellis et al. we get

$$c'^2 = c^2(1 - \frac{E_0^2}{E''^2} \cdot 10^4) \quad (7)$$

A comparison of (6) and (7) shows that though the approach of Ellis et al., is interesting, their limits do not exactly reproduce our exact relation (6). Finally, it may be reiterated that the just launched GLAST Gamma Ray Telescope of NASA would almost certainly shed further light on the matter.

3 New Particles

The physics community is expectantly awaiting the Large Hadron Collidor (*LHC*), as we are certain to get a wealth of new data with the potential to even transform Particle Physics. It is known that the standard model is in excellent agreement with experiments at energies around or less than $200GeV$. This is a theory of weak and electromagnetic interactions. However as noted in Section 1, this is not the whole story ([5, 6] and references therein). There are some important unanswered questions. These include

the question why the elementary particles have the masses which they are experimentally known to have, that is the question of the mass spectrum. There is also the case of the elusive Higgs Boson which is required in the theory for generating the mass of the particles. The Higgs Boson, despite several attempts, has not turned up. Could the *LHC* discover the Higgs Boson? Equally interesting, what if the Higgs Boson were not discovered even by the *LHC*?

Then there are subtler issues. For instance the dominance of matter over anti matter in the universe—this observational fact requires CP Violation, which indeed was observed way back in 1964 in the decay of *K* meson. Though this is in agreement with the standard model, it does not still explain the observed matter-anti matter ratio. In other words we need further sources of CP Violation. Incidentally this could also result from the Lorentz Symmetry Violation alluded to in Section 2.

Another important issue is that of Supersymmetry (SUSY). Though this has been an elegant theory which has even threatened to solve the as yet unsolved problem of the unified description of General Relativity and Quantum Theory, the fact is that it predicts a whole range of Supersymmetric particles which have not yet been detected. If some or all of these particles are detected by the *LHC*, that would be a major headway in Particle Physics and Quantum Gravity.

All this including the question of a Neutrino Mass would constitute what has been come to be known as physics beyond the standard model. This would also include the new paradigm of Dark Energy, which was indirectly detected through the acceleration of the universe by an observation of distant supernovae in 1998. Indeed the author's 1997 model had predicted this new cosmological scenario (Cf.ref.[1] and references therein). So it is no wonder that so many hopes are pinned on the *LHC*.

Finally there is also the related problem of Scale Invariance. This is a well studied problem, at least mathematically, in which we require that the physical laws remain unchanged if the length or energy scale of the problem is multiplied by some factor. However it has not been found as yet in the standard model. It appears that we may require what are called un particles for this to be the case [21].

In any case the *LHC* is bound to come up with as yet unknown particles. It is interesting that the author's 2003 mass spectrum formula viz.,

$$m_P = m \left(n + \frac{1}{2} \right) m_\pi \quad (8)$$

gives the mass of all known elementary particles. In the above equation m_P is the mass of the elementary particle in question and m_π is the mass of the π meson and m and n are positive integers. It is derived based on the QCD potential [22, 5, 6]. It gives the mass of all the known elementary particles with an error of about three percent or less. The subsequently discovered $D_s(2317)$ and the as yet unconfirmed $1.5GeV$ Pentaquark as also the $D_s(2632)$ and the more recent $4.43GeV$ meson, the so called Z charged mesons are also described by the above formula. It would be interesting to see if the new particles which are bound to be discovered by LHC would obey the formula (8).

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